3.30 Aiming Solution Functional Element Sensitivity

RADGUNS simulates the electromechanical, analog FCC that computes the aiming solution via transfer and coordinate transformation functions. After each scan period, the radar sends its computed target position to the fire-control computer. This information is accumulated and smoothed in the predictor circuit, which computes the targetõs position and velocity for a time t seconds earlier (t is the time delay needed by the predictor to make its calculation). The predictor is required for the computation of the targetõs future position. Once the targetõs position and velocity t seconds earlier are known, an estimate is used for the time t_p for a bullet/projectile to reach the target. The targetõs position t_p seconds in the future is predicted by assuming that the computed velocity of the target remains constant. Elevation angle corrections are made to account for the effects of gravity and drag, producing a superelevated target position. This is the point in space where the guns should be aimed for target intercept.

Iterative corrections are continuously made to t_p using a ballistic cam function. If the target becomes masked, the fire-control computer enters memory mode and continues to predict target positions using the last known velocity vectors in the FCC.

Data Items Required

Data Item		Accuracy	Sample Rate	Comments
8.1.1	Tracking range	±5 m	10 Hz	
8.1.2	Tracking azimuth	±0.1 deg	10 Hz	
8.1.3	Tracking elevation	±0.1 deg	10 Hz	
8.1.4	Commanded azimuth	±0.1 deg	10 Hz	
8.1.5	Commanded elevation	±0.1 deg	10 Hz	
8.1.6	Gun azimuth	±0.1 deg	10 Hz	
8.1.7	Gun elevation	±0.1 deg	10 Hz	

3.30.1 Objectives and Procedures

The FCC aiming solution is sensitive to target angular and radial velocities, and errors in target position produced by the radar. The method used to examine sensitivity of the aiming solution was to exercise *RADGUNS* under the following conditions:

a. Model mode: SNGL/RADR/LLL

b. Target RCS: 1.0 m^2

c. Target altitude: 200 m

d. Target speed: 50, 200, 300 m/s

e. Flight path: LINEAR, 0 and 1 K offsets
CIRCL1, 2000 meter radius

f. Radar type: RAD1

g. Guns: Enabled

h. Output: Commanded azimuth and superelevation angles

3.30.2 Results

The LLL tracking option forces azimuth, elevation, and range errors to zero. Thus, tracking errors did not affect the aiming solution computed. Table 3.30-1 contains the simulation run matrix used to evaluate the functional element, which was constructed to span a reasonable breadth of speeds, ranges, and flight paths. The zero offset and circular flight path cases were particularly designed to reduce the number of variables for each respective case.

TABLE 3.30-1. Simulation Run Matrix for Aiming Solution Functional Element.

Type	Velocity (m/s)	Variables	Constants
Linear, 0 K Offset Linear, 0 K Offset	50 300	Elevation angle Range	Azimuth
Circle, R = 2000 m Circle, R = 2000 m	50 200	Azimuth	Range Elevation
Linear, 1 K Offset Linear, 1 K Offset Linear, 1 K Offset	50 200 300	Azimuth Elevation Range	None

The method of analysis for this FE involved examination of the lead angle and superelevation angles for variations in target speed and range. Table 3.30-2 lists variable names used in the graphics of this section:

TABLE 3.30-2. Definition of Variable Names Used in Figures.

Variable	Definition
AZDEG	True azimuth angle in degrees
BETADEG	Commanded azimuth angle in degrees
BETAnnn	Commanded azimuth at nnn m/s velocity
ELDEG	True elevation in degrees
ELRATE	True elevation angular rate in degrees/second
GUNAZ	Gun azimuth pointing angle in degrees
PHIDEG	Commanded elevation angle in degrees
PHIDEGnnn	Commanded elevation at nnn m/s velocity

Seven simulation runs were analyzed for commanded azimuth and elevation variation with respect to time, range, speed, and the true azimuth and elevation values. Table 3.30-3 lists additional conditions applicable to each run:

TABLE 3.30-3. Additional Conditions Applicable to Test Runs.

Element	Status
Search Radar	Perfect Cuing
MTI	Off
FCC Model	First Order
Clutter	Disabled
Multipath	None
Terrain (Hills)	None
Countermeasures (Jamming)	None

Azimuth was investigated to determine sensitivity to velocity and range. Initial investigations of true versus commanded azimuth were for the zero K offset cases. For the slow moving, 50 m/s case, the commanded azimuth was a nearly perfect match to true azimuth, directly north at 0 deg until crossover, at approximately 138 s. At this time a break lock occurs with a corresponding poor angle tracking indication. Target reacquisition occurs at 143.6 s, after which time commanded azimuth is computed with nearly the same accuracy as the ingress portion. The fast-moving target causes the break lock at 22.9 s with reacquisition at approximately 27 s. The results in these two cases were as expected.

Linear flight paths at a 1 K offset were run for three different target speeds. Because the offset chosen was to the left of the threat, the lead angles (shown as BETADEG) were less than the corresponding true azimuths. Also, the difference between commanded and true azimuth would be expected to increase with target velocity. Figure 3.30-1 presents a composite of all three runs, showing true azimuth, commanded azimuth for each of the three velocities, and the corresponding range at measurement in meters. Note that the higher velocity runs have correspondingly increased differences between true and commanded azimuths (lead angle). The lead angle also increases as range decreases, the result of increasing angular tracking velocity.

To complete the azimuth investigations, outputs from two circular flight path runs were conducted at a constant radius of 2000 m in a clockwise direction for 60 s. As expected, the constant angular velocity of the flight path relative to the threat results in a constant lead angle. Table 3.30-4 summarizes the lead angle results of the two runs. Although the standard deviations from the simulation runs are relatively small, the lead angle computation varies almost linearly with velocity.

TABLE 3.30-4. Lead Angle Results.

Velocity (m/s)	Mean Lead Angle (deg)	Standard Deviation (deg)
50	5.53	0.17
200	24.69	0.20

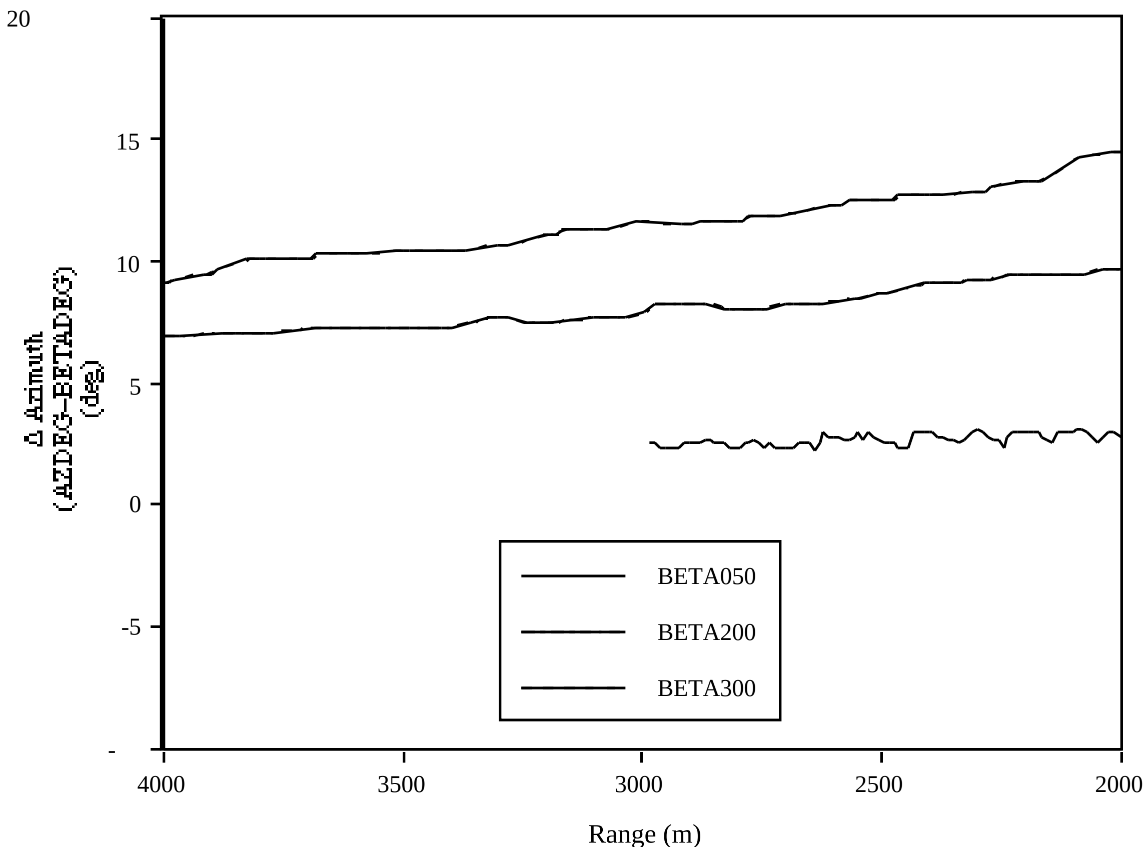

FIGURE 3.30-1. Difference Between True Azimuth and Command Azimuth (1-K Offset, Target Speed = 50, 200, and 300 m/s, Linear Flight Path).

Elevation angle variance was analyzed in the same manner as azimuth. True elevation was matched with the corresponding commanded elevation over a range of offset and airspeed combinations. For the zero-K offset cases, break locks occurred as the target flies directly over the threat, exceeding the maximum elevation angle for the tracking radar.

Figure 3.30-2 shows the comparative differences between actual and commanded elevation for the slow and fast, zero-offset cases. The figure illustrates the dependence of superelevation on target range rate (radial velocity) and the increasing pointing error that occurs until the target passes over the threat at about 500 m.

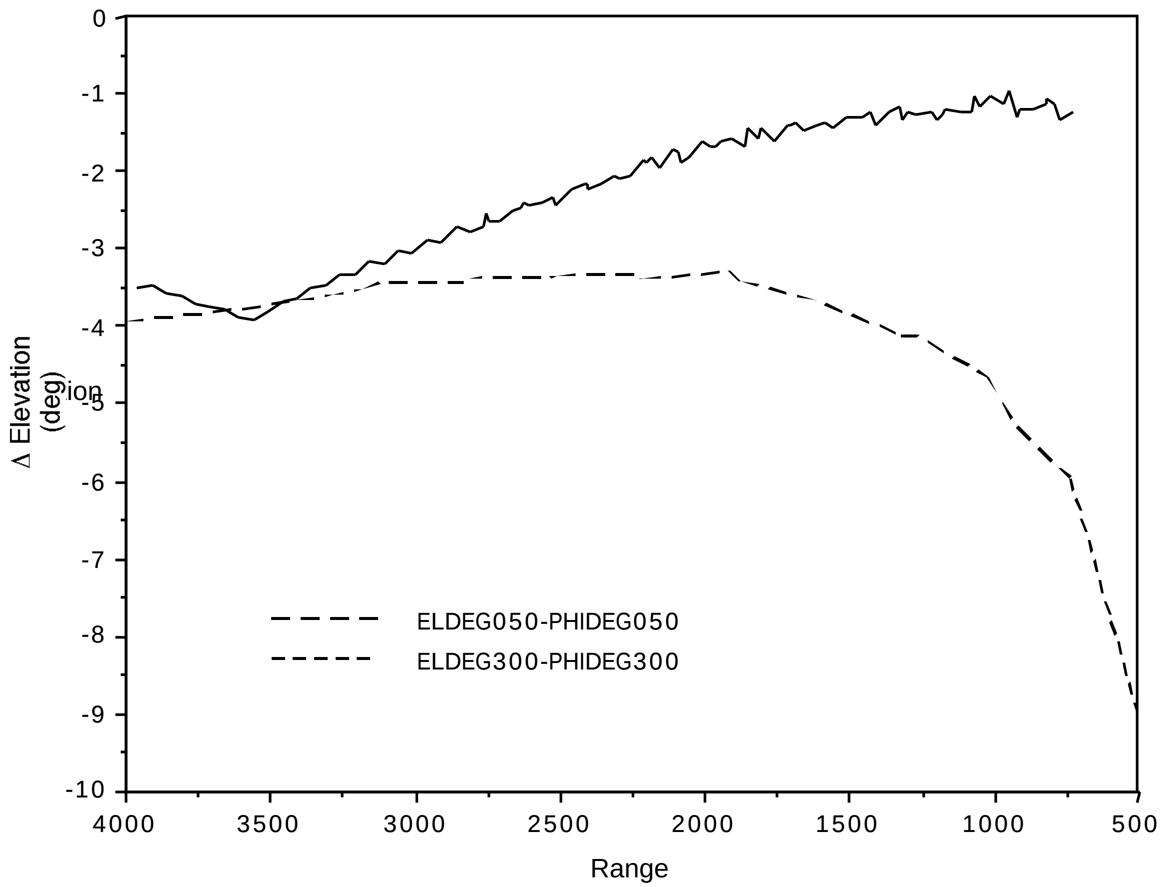

FIGURE 3.30-2. Difference Between True Elevation and Command Elevation (0-K Offset, Target Speed = 50 and 300 m/s, Linear Flight Path).

Figure 3.30-3 displays the composite for the 1-K offset cases as a function of range. In this graph, the expected lower commanded elevation associated with longer target ranges is apparent. Note also that as velocity increases, superelevation decreases due to the higher closure rate of the target.

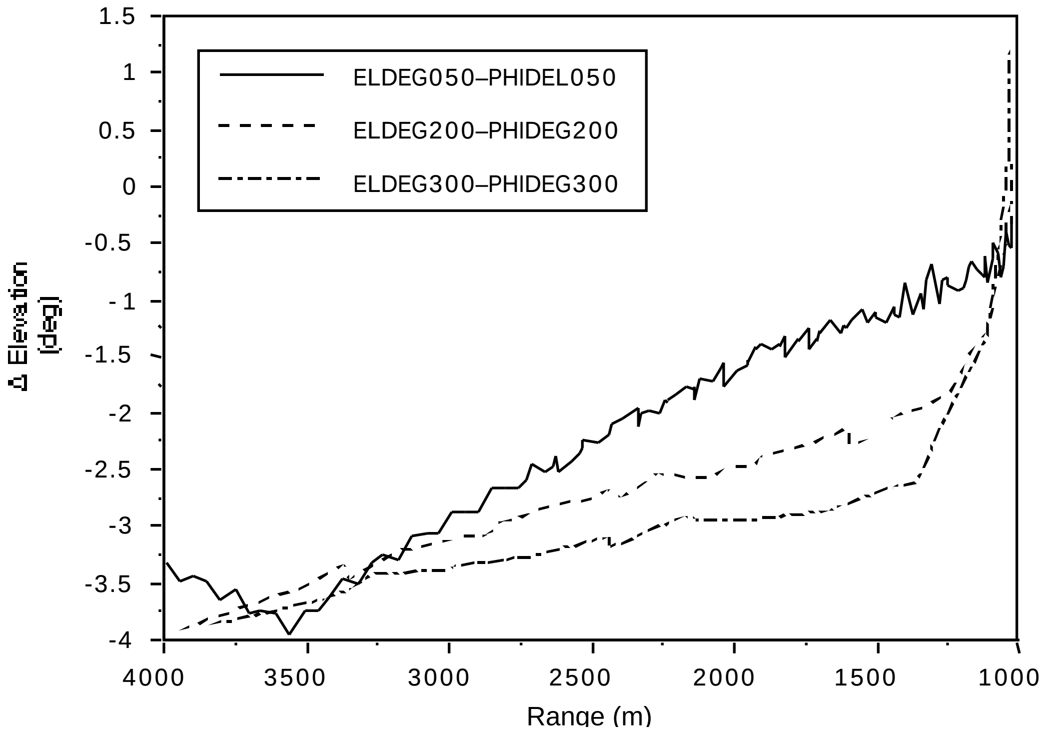

FIGURE 3.30-3. Difference Between True Elevation and Command Elevation (1-K Offset, Target Speed = 50, 200, and 300 m/s, Linear Flight Path);.

Finally, the circular flight paths were investigated for elevation angle variance. As expected, the commanded elevation angles remained essentially constant during each run as shown in Figure 3.30-4.

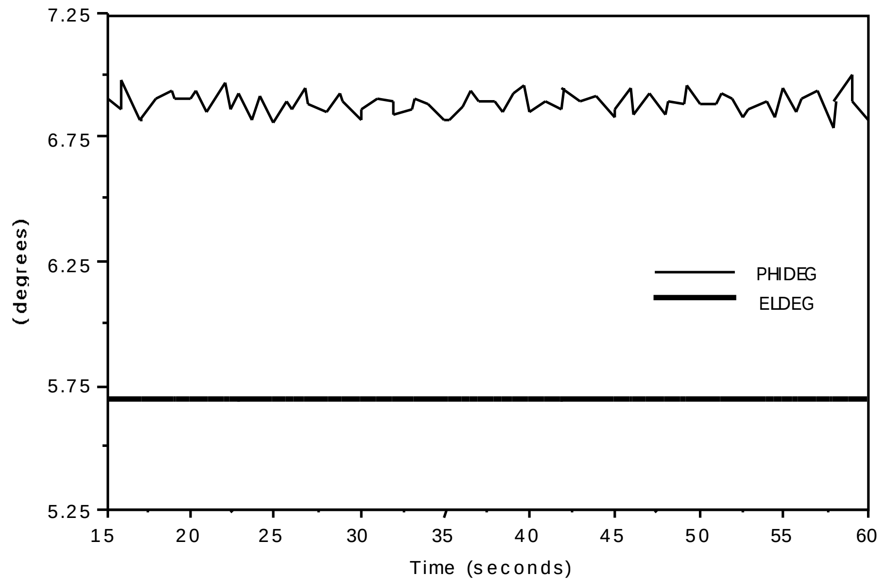

FIGURE 3.30-4 True Elevation and Command Elevation (Target Speed = 200 m/s, Circular Flight Path).

3.30.3 Conclusions

The aiming solution FE is sensitive to target velocities and corresponding flight path geometries. The number of possible permutations of flight path configurations and velocities is infinite. Nevertheless, for target velocities ranging from stationary to approximately 300 m/s and within effective gun ranges, aiming solution is proportional to target velocity and is moderately sensitive to the same.